

the operational state as set by the push-button (e.g., where the button is connected to an electromechanical control device such as an electrical switch).

**[0025]** For example, if a push-button has been configured to control the operational state of a motor vehicle rear-window defogger (either on or off), a reconfigurable bi-stable device as described herein could be used where manual pressing of the button moves the deformable panel **14** from the first or upper stable position to a second or lower stable position, thereby activating an electrical switch to close a circuit and activate the rear-window defogger. In order to prevent overheating and potential damage to the defogger components, such units are typically controlled by an auto shutoff controller or circuit that shuts the unit off after a predetermined period of time or if other conditions (e.g., high temperature) are reached. When the control circuit or electronic controller initiates the auto shutoff of the defogger (or any other device being controlled by the push-button), the SMA or piezoelectric actuator(s) can be activated to move the deformable panel from its second or lower stable position back to the first or upper stable position, thereby opening the circuit and deactivating the rear window defogger.

**[0026]** In other exemplary embodiments, it may be desirable to use SMA or piezoelectric actuator(s) to controllably move the deformable panel **14** in either direction between the first and second stable positions or between the second and first stable positions, such as with the device of FIG. 3. Again in the motor vehicle context (although clearly not limited to motor vehicle systems), many devices may be controllably activated and deactivated by controllers or control circuitry depending on inputs from various sensors. Vehicle headlights or other lighting systems may be controllably activated and deactivated depending on input from ambient light sensors, windshield wipers may be controllably activated and deactivated based on sensors that detect the presence of water droplets on the windshield, heating and cooling systems may be controllably activated or deactivated depending on input from temperature sensors, and many other examples of course exist or may be developed. For such systems, a device such as the one represented in FIG. 3 may be used where the controlled device may be activated either by manual pressing of the button moves the deformable panel **14** from the first or upper stable position to a second or lower stable position, or by system control from a controller activating the SMA actuator member **17** to move the deformable panel from the first or upper stable position to a second or lower stable position. The controlled device may be deactivated by system control from an electronic controller activating the SMA actuator members **16**, **16'** to move the deformable panel from the second or lower stable position to the first or upper stable position. Alternatively, user input could be used to deactivate the controlled device by using a touch sensor associated with deformable panel **14** to sense when it is pressed while in the second or lower position, which input would cause the electronic controller to actuate the SMA actuator members **16**, **16'** to move the deformable panel from the second or lower stable position to the first or upper stable position.

**[0027]** Various other exemplary embodiments disclosed herein can further enhance the available design and operation options for control devices like push-buttons. For example, when the elastic member **22** in the embodiments of FIGS. 6 and 7 comprises an SMA material, the shape memory capability of the elastic member can allow for the deformable panel **14** to assume different bi-stable configurations with

different upper and lower stable positions. This exemplary device could thus be used to control devices with more than simple on-off controlled states (e.g., different speeds for a windshield wiper control) and the relative height of the stable positions of the deformable panel would represent the relative operational state of the controlled device. User input could be received from a touch sensor associated with the deformable panel followed by system response changing the position of the deformable panel by actuation of the SMA elastic member **22**. In another exemplary embodiment, a push-button or touch pad may be designated to perform multiple different functions (e.g., numbers versus letters versus symbols on a mobile phone), and the relative height of the stable positions of the deformable panel **14** could be set to correspond to different functions assigned to the push-button or touch pad to serve as a visual and/or tactile cue of the currently assigned function.

**[0028]** Shape memory alloys useful for the SMA actuator members and SMA elastic members described herein are well-known in the art. Shape memory alloys are alloy compositions with at least two different temperature-dependent phases. The most commonly utilized of these phases are the so-called martensite and austenite phases. In the following discussion, the martensite phase generally refers to the more deformable, lower temperature phase whereas the austenite phase generally refers to the more rigid, higher temperature phase. When the shape memory alloy is in the martensite phase and is heated, it begins to change into the austenite phase. The temperature at which this phenomenon starts is often referred to as austenite start temperature ( $A_s$ ). The temperature at which this phenomenon is complete is called the austenite finish temperature ( $A_f$ ). When the shape memory alloy is in the austenite phase and is cooled, it begins to change into the martensite phase, and the temperature at which this phenomenon starts is referred to as the martensite start temperature ( $M_s$ ). The temperature at which austenite finishes transforming to martensite is called the martensite finish temperature ( $M_f$ ). It should be noted that the above-mentioned transition temperatures are functions of the stress experienced by the SMA sample. Specifically, these temperatures increase with increasing stress. In view of the foregoing properties, deformation of the shape memory alloy is preferably at or below the austenite transition temperature (at or below  $A_s$ ). Subsequent heating above the austenite transition temperature causes the deformed shape memory material sample to revert back to its permanent shape. Thus, a suitable activation signal for use with shape memory alloys is a thermal activation signal having a magnitude that is sufficient to cause transformations between the martensite and austenite phases.

**[0029]** The temperature at which the shape memory alloy remembers its high temperature form when heated can be adjusted by slight changes in the composition of the alloy and through thermo-mechanical processing. In nickel-titanium shape memory alloys, for example, it can be changed from above about 100° C. to below about -100° C. The shape recovery process can occur over a range of just a few degrees or exhibit a more gradual recovery. The start or finish of the transformation can be controlled to within a degree or two depending on the desired application and alloy composition. The mechanical properties of the shape memory alloy vary greatly over the temperature range spanning their transformation, typically providing shape memory effect, superelastic effect, and high damping capacity. For example, in the mar-